REPORT 84-013-7799-11
FHWA/NJ-84-013

SOLAR DOMESTIC HOT WATER SYSTEM HARDING TOWNSHIP REST AREA BUILDING, I-287

Interim Report
Design and Installation

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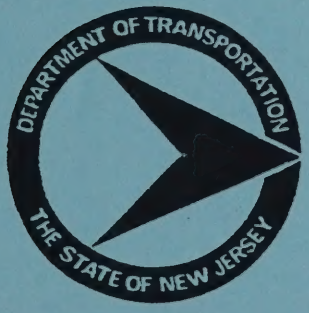

February 1984

Prepared By
New Jersey Department of Transportation
Division of Research and Demonstration
Bureau of Transportation Technology Research
In Cooperation with
U.S. Department of Transportation
Federal Highway Administration

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TECHNICAL REPORT STANDARD TITLE PAGE

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
FHWA/NJ-84/013		

4. Title and Subtitle	5. Report Date
Solar Domestic Hot Water System Harding Township Rest Area Building, I-287	February 1984
	6. Performing Organization Code N.A.
7. Author(s) S. R. Sasor and J. Flesch	8. Performing Organization Report No. 84-013-7799
9. Performing Organization Name and Address New Jersey Department of Transportation Division of Research & Demonstration 1035 Parkway Avenue, CN 600 Trenton, NJ 08625	10. Work Unit No. N.A. 11. Contract or Grant No. DOT-FH-15-386
12. Sponsoring Agency Name and Address New Jersey Department of Transportation Division of Research & Demonstration 1035 Parkway Avenue, CN 600 Trenton, NJ 08625	13. Type of Report and Period Covered Interim Report Nov. 1979 - Nov. 1982 14. Sponsoring Agency Code

15. Supplementary Notes

Prepared in cooperation with the U.S. Department of Transportation, Federal Highway Administration.

16. Abstract

This interim report discusses the basic design and installation of the solar domestic hot water system in the Harding Township rest area building adjacent to I-287 in Morris County, New Jersey. It includes information on the designers and installer, describes the installed equipment in some detail, mentions problems in installation, and presents installation costs. In addition, this report briefly discusses the plans for monitoring and evaluating the system. The Appendices of the report contain an as-built schematic, installation contract specifications, a detailed monitoring plan, and the contractor's guide to maintenance and operation.

A retrofit solar domestic hot water system was designed in-house by NJDOT, and installed by a contractor during the summer and fall of 1982 in the Harding Township rest area building. It has been operational since November 1982 and its performance is being monitored and evaluated.

At a later date, a final report will be prepared which will present an evaluation of the solar domestic hot water system's performance and cost. Operational experience, an owner evaluation, and a revised life cycle cost study will be included.

17. Key Words	18. Distribution Statement
Solar Energy, Renewable Energy Sources, Solar Domestic Hot Water Systems, Retrofit Systems, Solar Collectors & Storage Tanks, Performance Monitoring	No restrictions

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	72	

Form DOT F 1700.7 (8-69)

ACKNOWLEDGEMENTS

The authors would like to gratefully acknowledge the contributions made by all members of the Bureau of Transportation Technology Research (TTR) who participated in this study. In particular, we acknowledge the efforts of Tom Fuca who initiated the study and was the project manager for the design and installation phases. Tom prepared the designs and specifications for the solar domestic hot water and monitoring systems in a cooperative effort with Dave Byers of the Bureau of Landscape Architecture, Division of Design. In addition, the following tasks were completed either by Tom or under his direction: preparation of the study work proposal, life cycle cost analysis, monitoring plan, and public information display, and the inspection and operational testing of the installed systems.

Word processing of the rough draft and final manuscript of this report was completed by Barbara Blue and Janice Rita of TTR; and drafting of figures, by Bill Crowell also of the Division of Research.

Also members of the Bureau of Plant Engineering and Operations, Division of Central Services, provided assistance during the procurement and installation of the solar domestic hot water system.

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SUMMARY

To reduce energy costs and to conserve nonrenewable energy sources, such as oil and gas, the New Jersey Department of Transportation (NJDOT) decided to examine solar energy as an alternative energy source for highway-related applications. Being aware that Federal Highway Administration (FHWA) Demonstration Projects Division funding was available for this purpose, NJDOT surveyed the State for highway-related uses of solar energy that would be feasible and cost-effective. The use of solar energy to heat domestic hot water at a highway rest area fulfilled these requirements.

This study began when a grant to retrofit the Harding Township rest area building in Morris County, New Jersey with solar domestic hot water was approved under FHWA Demonstration Project No. 52, Solar Energy for Highway Uses. The Harding Township rest area is located adjacent to northbound Interstate 287 approximately 3 miles south of Morristown.

In accordance with the demonstration project contract, NJDOT completed the design and specifications for the solar domestic hot water (DHW) and monitoring systems, as well as a life cycle cost analysis, a monitoring plan, and a public information display -- all received approval from FHWA. With design approval, a contract was let for installation of the system in the Harding Township rest area building. Though there were difficulties in obtaining qualified bidders, a contract was eventually awarded to the low bidder, All Pipe Plumbing and Heating Co. of Succasunna, New Jersey. Procurement and installation of the solar DHW system was completed during the summer and fall of 1982 with only

minor problems and no change orders. Daily inspection of construction was performed by NJDOT personnel. A month of operational testing of the system followed, and after proper operation was demonstrated, the installation was accepted as fulfillment of the contract. The contract cost was approximately $12,000 for the solar domestic hot water system and $4,800 for the monitoring system. Fully automatic operation of both systems began on November 8, 1982.

INTRODUCTION

America's primary sources of energy are fossil fuels such as oil and natural gas. These fuels are nonrenewable energy sources whose reserves are diminishing; in addition, the availability of oil can be manipulated by unfriendly nations. A significant portion of our fossil fuel consumption is due to transportation and transportation related activities. Though automotive fuels account for most of the consumption for transportation, fossil fuels are also consumed in operating and maintaining the Nation's highways. In light of this, the Federal Highway Administration's Demonstration Projects Division initiated Demonstration Project No. 52, Solar Energy for Highway Uses, to encourage state transportation agencies to explore solar energy as an alternative energy source for highway-related applications.

Accordingly, the New Jersey Department of Transportation requested and received funding through Demonstration Project 52 for a solar energy project at the Harding Township rest area building in Morris County. At the rest area, domestic hot water is preheated by solar energy and supplied to 16 wash basins in the rest rooms. The Harding Township rest area is frequented by tourists visiting the historic Morristown area as well as New Jersey residents. From spring to fall approximately 300 people per day use the rest area building from Monday through Friday with this number rising to 500 people daily on Saturday and Sunday. With this amount of usage, a life cycle cost analysis indicated that the hot water demand would be high enough for this retrofit solar domestic hot water heating system to be economically feasible. In addition, the rest area affords an excellent opportunity to demonstrate this solar energy application to the general public through a public information display consisting of a brochure which describes the solar energy system.

THE BASIC SYSTEM

The Harding Township rest area building, which is approximately 55 feet by 65 feet and 15 feet high with a flat roof (see Photograph 1, next page), was constructed in the summer of 1975 and domestic hot water for the rest rooms was provided by a 120 gallon electrically heated hot water tank. Consequently, the rest area was retrofit with the solar water heating system. The contract for the solar domestic hot water system was awarded on June 4, 1982, installation was completed during the summer and fall, and the entire system became fully operational in November 1982.

The basic solar domestic water heating system consists of four flat plate solar energy collectors mounted facing south on the roof, a 120 gallon solar preheat storage tank, the 120 gallon electrically heated storage tank as backup, a circulating pump and controller, antifreeze fluid, monitoring instrumentation, and assorted pipes, valves and fittings. The system operates automatically with the circulating pump on when useable heat is available at the collectors which are shown mounted on the rest area roof in Photograph 1. The antifreeze solution, which travels in a closed loop, transfers heat from the collectors to the water in the preheat storage tank. The washrooms at the rest area are provided with 110°F hot water. Thus if solar energy can not heat the tap water to this temperature, than the electrical backup system will do so. By preheating the cold supply water, solar energy reduces the use of electricity and produces a direct dollar savings.

PHOTOGRAPH 1. HARDING TOWNSHIP REST AREA BUILDING

STUDY SCOPE

The scope of this demonstration project includes design of the solar energy domestic hot water heating system and a performance monitoring system, completion of a life cycle cost analysis, preparation of a public information display, preparation of a bid package for system installation, procurement and installation, operation of the system for a period of one year, monitoring of performance, and system evaluation. Tasks from design to construction of the solar energy heating and monitoring systems were funded under a grant from the Demonstration Projects Division while operation of the system and evaluation of its performance are funded through the Highway Planning and Research (HP&R) Program.

This report covers the procurement and installation phases of this study. A final report evaluating the solar domestic hot water system's performance for one year will also be prepared. It will include an updated life cycle cost analysis reflecting actual installation costs, hot water demand, and electricity rates.

DESIGN OF THE SOLAR DOMESTIC HOT WATER SYSTEM

The Harding Township rest area solar domestic hot water (DHW) system was designed in-house by NJDOT's Division of Research in cooperation with the Bureau of Landscape Architecture of the Division of Design.

DESIGN CRITERIA

The design of the solar water heating system was based on the performance criteria described below. The design guidelines and material considerations contained in the FHWA's Solar Heating Systems Design Considerations also served as design criteria for the solar DHW system.

Hot Water Heating Demand

A hot water usage of 240 gallons per day was used for design purposes. This was based on an estimate that 400 tourists would visit the rest area building per day each using 0.6 gallons. Water inlet temperature was assumed as $50^{\circ}F$, while the outlet temperature to the rest rooms was assumed as $100^{\circ}F$. From these assumptions the annual heating demand was calculated as 36.5 million BTU.

Collector Sizing and Orientation

The criterion for final sizing of collectors was that the maximum number of BTUs should be captured per dollar invested. Initially, however, collectors were sized based on a 60% solar energy contribution to the annual hot water heating demand. Total collector area in square feet was determined from the BTUs

supplied yearly per collector* which was calculated from meteorological data (average solar insolation) for the latitude of Trenton, New Jersey. For final sizing, a life cycle cost analysis indicated the optimum total collector area and accordingly, a total area of 85 square feet consisting of four collectors was specified to provide approximately 73 percent of the annual hot water heating demand.

Collectors were oriented to provide the highest average efficiency during the season of peak use of the rest area building. It was estimated that peak use would occur in the summer, therefore, the collector array was positioned accordingly.

Safety and Reliability

These criteria included the ability of all components of the solar DHW system to safely withstand exposure to the minimum and maximum pressures and temperatures expected to occur during the life of the system. This led to the specification of solar collector panels and a heat transfer fluid that provided both overheating and freeze protection. Another safety related criterion was that potable water to the rest rooms should not be contaminated by toxic substances in case of accident. Consequently, a non-toxic heat transfer fluid was specified.

Heat Loss of Storage Tanks

The heat loss from the preheat storage tank and the existing electrically heated tank was to be minimized. Thus, it was specified that both storage tanks were to be insulated to an R-value of at least 11.

*Each collector had an area of about 21 ft^2.

Mode of Operation

Operation was to be automatic with the circulating pump of the collector loop turned on whenever the collector temperature was higher than the temperature of the preheat storage tank by an amount which allowed for efficient transfer of heat. When this condition was not met, the circulating pump was to be turned off.

Performance Monitoring System

A monitoring system was required to measure the amount of incident solar radiation in the plane of the solar collectors, the amount of heat transferred to the preheat storage tank, the total heating load demand, the solar contribution to the heating demand, and the electrical energy required to operate the solar DHW system and the auxiliary heating tank.

SYSTEM DESIGN

The solar DHW system components were selected based on the above design criteria and are shown in Figure 1, next page.* The main components of the solar water heating system are solar collectors, heat transfer fluid, a circulating pump, differential temperature controller, solar preheat storage tank with a heat exchanger coil, electrically heated auxiliary tank, mixing valve, and associated pipes, valves, and fittings.

*Details of system components are given in the installation section of this report on pages 15-32, and in the system specifications in Appendix B, pages 37-51.

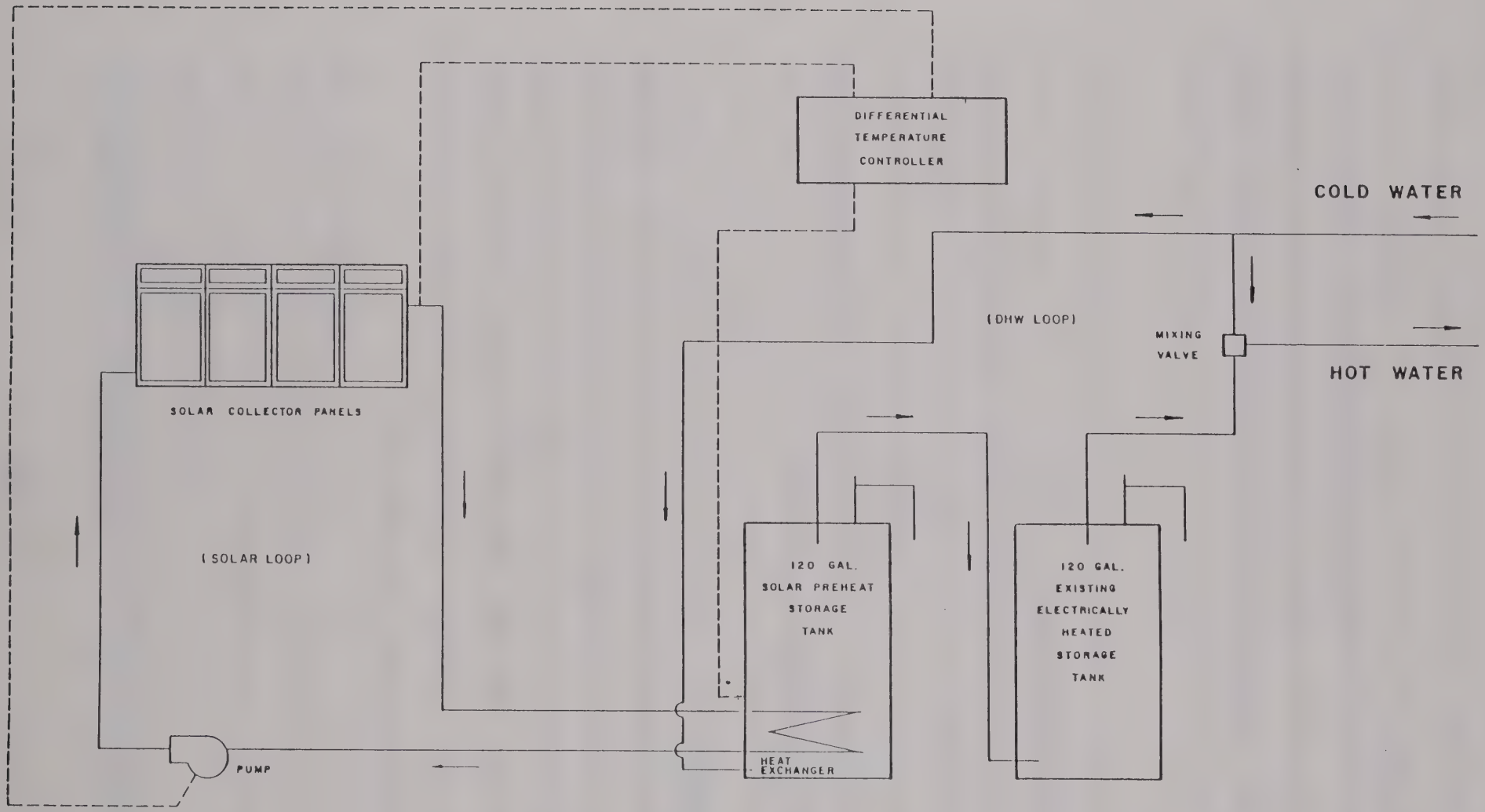


Figure 1. SOLAR DOMESTIC HOT WATER SYSTEM

HARDING TOWNSHIP REST AREA, I-287

Solar Loop

Four flat plate solar energy collectors are mounted in an array on the roof of the rest area. They face due south and are tilted at an angle of 30° above the horizontal. Each collector has a black absorber plate with copper tubing through which the heat transfer fluid flows.

The heat transfer fluid is a non-toxic propylene glycol which protects the solar loop from freezing down to a temperature of minus $30^{\circ}F$. Heat rejection panels on the solar collectors protect the antifreeze heat transfer fluid from excessively high temperatures.

A circulating pump forces the heat transfer fluid through the solar loop which includes the collectors and the heat exchanger coil of the preheat storage tank. A differential temperature controller turns on the circulating pump when the temperature of the solar collector panels is at least $20^{\circ}F$ higher than that of the water in the preheat storage tank. The controller turns the pump off when the difference in temperature is less than $5^{\circ}F$.

Domestic Hot Water Loop

Two hot water storage tanks provide a total of 240 gallons of storage. The existing 120 gallon tank has an electrical back-up heating coil. The solar preheat storage tank also has a 120 gallon capacity, and it contains the heat exchanger coil of the solar loop. Both tanks are wrapped with fiberglass insulation to minimize heat losses. Valves are located so that the tanks can be operated separately or in series.

A mixing valve located at the end of the domestic loop automatically reduces the temperature of the hot water supplied to the rest rooms to $110^{\circ}F$ if required.

System Piping

The components of the solar loop and the domestic hot water loop are connected by 3/4 inch diameter pipe which is protected with a weatherproof outer casing and is insulated with an inner layer of urethane foam. Gate valves and other fittings are placed in the connecting lines to provide for proper system operation.

Monitoring Equipment

Equipment to monitor the performance of the solar water heating system was included in the design. A pyranometer and accumulating integrator measure and record the amount of solar radiation striking the solar collectors. BTU meters, consisting of an accumulating integrator circuit, temperature sensors, and flow meters, measure the amount of heat supplied to the preheat storage tank, the domestic water heating demand, and the solar contribution to this demand. Kilowatt-hour meters record the electrical energy required to operate the solar water heating system and the back-up electrical heating elements in the auxiliary storage tank.

SYSTEM OPERATION

The solar water heating system works in the following manner. Solar radiation is absorbed by roof mounted solar collector panels. The temperature of the collector absorber plate increases to the point where enough useable heat is available to increase the temperature of the stored preheated water. The differential temperature controller turns the circulating pump on, and as the antifreeze fluid flows through the tubing of the collector absorber plate it picks up heat. The antifreeze fluid then travels via piping through a heat exchanger coil inside the preheat storage tank and transfers heat to the surrounding

domestic water. The domestic hot water flows from the storage tanks to the rest rooms as required. If the water from the solar preheat tank is less than $110^{\circ}F$, it is heated to this temperature in the electrically heated tank prior to use in the rest rooms. If the preheat water is greater than $110^{\circ}F$, the electrically heated tank remains off and the mixing valve automatically reduces the water temperature to $110^{\circ}F$ before it enters the rest rooms.

SELECTION OF INSTALLER

After completion of design, a contractor to install the solar domestic hot water system in the Harding Township rest area building was selected through the bid process. NJDOT prepared a bid package consisting of the solar DHW system plans and specifications*, the standard regulatory contract language pertaining to affirmative action, minority business interests, laws against discrimination, etc., and disclaimers. The contract was advertised through DOT in July 1981; however, no bids were received. Subsequent efforts to readvertise the project through DOT were also unsuccessful since competent solar contractors could not meet DOT's stringent prequalification requirements which were developed with large highway projects in mind.

At this point, it was decided to advertise the project through the Division of Building and Construction of the Department of Treasury because Treasury's prequalification requirements were less stringent. This advertisement necessitated the preparation of another bid package, and coordination of our efforts with Treasury resulted in additional delays. Advertising of the installation contract through Treasury took place in April 1982. Bids were received and reviewed, and the contract was awarded to the lowest bidder in compliance with the terms of the contract.

Accordingly, the contract for installation of the solar DHW system in the Harding Township rest area building was awarded on June 4, 1982 in the amount of $16,745 to the All Pipe Plumbing and Heating Company, P. O. Box 315, Succasunna, New Jersey, 07876.

*Specifications for the Harding Township rest area solar DHW system are included as Appendix B, pages 37-51.

INSTALLATION OF THE SOLAR DHW SYSTEM

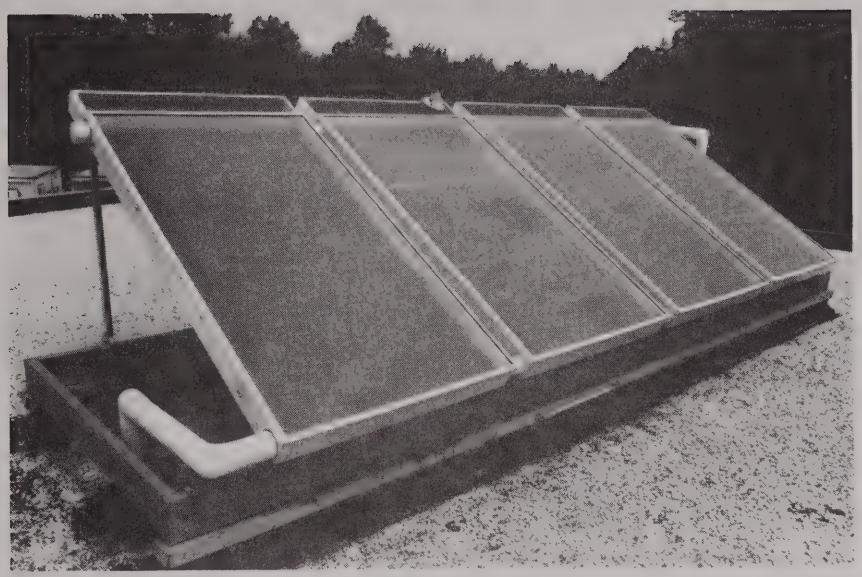
The prime contractor (All Pipe Co.) subcontracted the installation of the solar DHW system in the Harding Township rest area building to Solar Innovations of 175 River Road, Flanders, New Jersey, 07836. Construction of the system began in August 1982 and after an operational testing period, the system was accepted by NJDOT on November 8, 1982.

Below is a description of the equipment that was installed in the domestic hot water and monitoring systems. This description includes the make-up and function of the equipment, and in most cases the equipment manufacturer is noted as well. Though not installed under the system contract, the existing electrically heated storage tank is described in this section since it was one of the major components of the system. The as-built system schematic in Appendix A, page 36, shows how all of the equipment mentioned below fits into the system. Detailed specifications for the equipment are contained in Appendix B.

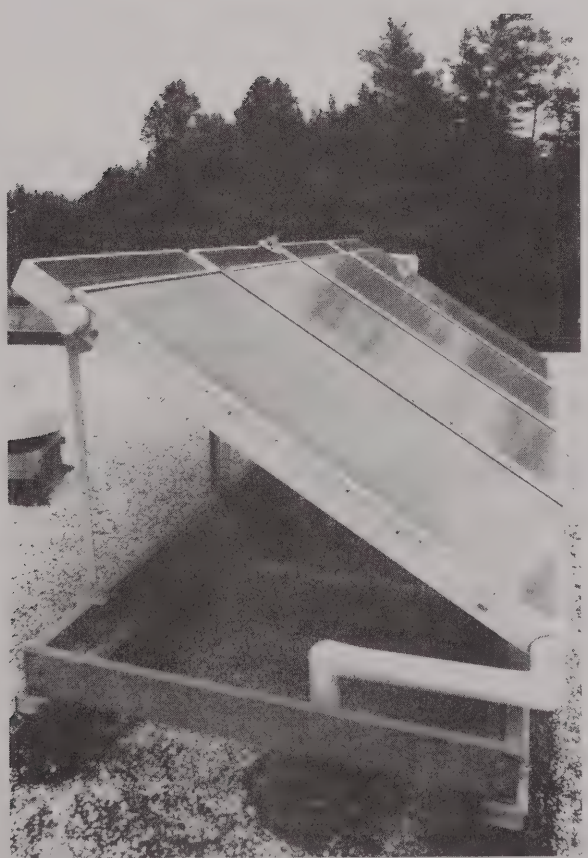
DOMESTIC HOT WATER SYSTEM

Solar Collector Panels

Four Daystar 1600/TLS flat plate copper collector panels are used to collect the solar energy. See Photographs 2 & 3, page 16. Each panel has a cover plate made of tempered glass 3/16" thick, which has a low iron content, and a net aperture area of 21.1 square feet. The panel case, which has gross dimensions of 73" x 44" x 5", is made of aluminum and has a coating of baked white polyester enamel. The inside of the case is insulated with a high temperature isocyanurate foam with a polyvinyl flouride moisture barrier. The foam is 1.5"



PHOTOGRAPH 2. SOLAR COLLECTOR PANELS



PHOTOGRAPH 3. SOLAR COLLECTOR PANELS

thick in the back and 1" thick on the sides. The density of the insulation is 2.5 lbs/ft^3, and the thermal conductivity K = 0.13 BTU-in/hr-ft^2-^oF @ 70^o.

Also inside the case is an absorber consisting of a copper plate attached to parallel 1/4" copper tubing. The surface of the absorber is coated with a high temperature black chrome selective coating to provide maximum solar absorption. The fluid capacity of one solar panel is 0.45 gallons and net weight is 145 lbs. empty. Flexible silicone rubber hoses which are resistant to chemical attack by the antifreeze fluid are used to connect the solar panel manifolds to each other. The hoses are secured to the manifolds by stainless steel clamps of the worm bank type.

The solar panels absorb solar radiation and transfer heat to the antifreeze fluid which flows through the copper tubing contained in the absorber plate.

A. Temperature Limiting System - Under certain conditions (high insolation, stagnation, and no demand) the solar collectors can generate temperatures in the 325^oF - 400^oF range. While the collectors are designed to withstand these temperatures, such high temperatures may exceed the operating temperature limit of the heat transfer fluid and could cause irreversible degradation or fluid loss due to boiling. Therefore, a temperature limiting system (TLS) is attached to each collector to automatically keep heat transfer fluid temperatures at acceptable levels. The TLS panels, which are 8" high and 44" wide, are shown attached to the top of the collectors in Photographs 2 & 3, page 16.

The limiting system panels contain copper tubing with thin plates attached to the tubing surface. This greatly increases the surface area exposed to the

outside air. When the heat transfer fluid reaches a preset temperature (about 225°F) , a valve in the collectors opens and permits the fluid to flow into the temperature limiting panels where heat is dissipated to the outside air.

The Daystar 1600/TLS collector panels which come with the temperature limiting system were manufactured by Daystar Corporation, 90 Cambridge Street, Burlington, Massachusetts, 01803.

B. Roof Support Curbs - The solar collector panels are attached to a steel frame which is mounted to two support curbs which are bolted to the roof of the rest area building. These support curbs have a 2 1/2" raised cant to accomodate the built-up roof. See Photographs 2 & 3, page 16. The roof support curbs are manufactured by S & L Manufacturing Co., 241 Wilson Avenue, Newark, New Jersey, 07105.

Water Storage Tanks

A. Solar Preheat Tank - A Sepco C-120SNR-1-40 solar water tank of 120 gallon nominal capacity stores the preheated domestic water. This tank is constructed of heavy duty steel and is lined inside with a 1/2" seamless hydraulic stone layer. It contains a copper tubing heat exchanger near the bottom with an area of approximately 40 square feet. The water in the tank is heated by antifreeze fluid which dissipates heat as it passes through the tank heat exchanger. A high pressure and temperature relief valve is mounted on the top of the tank. The outside of the tank is insulated with 2 inches of 2 lb. density fiberglass which is covered with a heavy-gauge steel jacket.

A thermal insulating blanket of 1 1/2 inches of 4.5 lb. density fiberglass tank wrap was placed around the solar preheat tank; i.e., over the steel jacket, as

shown in Photograph 4, page 23. The location of the solar tank is shown in the system schematic, page 36.

The Sepco tank was manufactured by the Vaughn Corporation, 386 Elm Street, Salisburg, Mass., 01959; and the thermal insulating blanket, by York Industries Corporation, 360 Hurst Street, Linden, New Jersey, 07036.

B. Auxiliary Storage Tank - This hot water heating tank has a nominal 120 gallon capacity and is located alongside the solar preheat tank as shown in Photograph 4. This tank was installed in 1975 when the rest area building was originally constructed. With the installation of the solar DHW system, five of the six 6-kW electrical heating elements were disconnected. Now only the third element from the top remains connected and the tank thermostat is turned down to its lowest setting (120°F). A high temperature and pressure relief valve is mounted on top of the tank.

The auxiliary tank has several inches of fiberglass insulation inside its outer jacket. The entire tank is covered with a thermal insulating blanket of 1 1/2 inches of 4.5 lb. density fiberglass tank wrap, the same wrap used for the solar preheat tank.

As shown in the system schematic on page 36, the preheated water from the solar tank passes directly into the auxiliary tank. If this water is over 120°F, then the electrical element of the auxiliary tank is not energized; in this manner electricity is saved. The hot water from the auxiliary tank passes through an automatic mixing valve and into the rest rooms for use by the public.

Heat Transfer Fluid

Solargard PL antifreeze solution is used in the solar collector loop as the heat transfer medium, absorbing heat at the collectors and giving off heat at the solar tank heat exchanger. This solution, which is non-toxic and non-flammable, is composed of water and over 50% by weight of propylene glycol. Solargard PL also contains an inhibitor, potassium phosphate, to reduce th corrosive effects of the fluid on the copper piping by maintaining a pH of at least 8.0. The antifreeze solution protects the solar loop from freezing down to -30°F and is capable of withstanding stagnation temperatures of up to 350°F without chemical degradation. Solargard PL is manufactured by Daystar Corporation, 90 Cambridge Street, Burlington, Mass., 01803.

Circulating Pump

A Taco 008-F2 solar cartridge pump circulates the heat transfer fluid in the solar loop. Operation of the circulating pump is regulated by the differential temperature controller which will be described below. The pump has a 1/25 HP motor with low energy consumption (0.75 AMP) which turns at a rate of 3250 RPM. Pump components exposed to the propylene glycol solution are corrosion resistant. Periodic maintenance is not required because of water lubricated bearings. This circulating pump is specifically designed for residential and light commercial solar systems. The circulator is manufactured by Taco Inc., 1160 Cranston Steet, Cranston, Rhode Island, 02920.

Differential Temperature Controller

The circulating pump is automatically regulated by a C-100 Energy Manager differential temperature controller. The controller turns the circulator on when there is a temperature difference of 20°F between the collector panels

and the solar preheat storage tank. The controller turns the circulator off when this temperature difference is 5°F. Collector and solar tank temperatures are measured by sensors fastened to the collector absorber plate and the side of the storage tank, respectively. In addition, the controller limits the water temperature in the solar preheat tank by shutting off the circulator when the tank temperature reaches 180°F.

The controller also monitors three other temperature sensors and displays with an LED readout the measured values in sequence when a sensor select button is pushed. The three sensors measure the temperatures in and out of the heat exchanger, and at the exit point from the solar tank as shown in the schematic on page 36. All system temperature sensors are thermistors. To detect problems, the controller's LED digital display flashes if the temperature being monitored is outside the range 32°F to 212°F or if a short or open circuit exists in sensor or wiring. Power consumption of the controller is 15 watts maximum. The differential temperature controller is manufactured by Independent Energy Inc., P.O. Box 732, 42 Ladd Street, East Greenwich, Rhode Island, 02818.

Piping, Valves, and Other Fittings

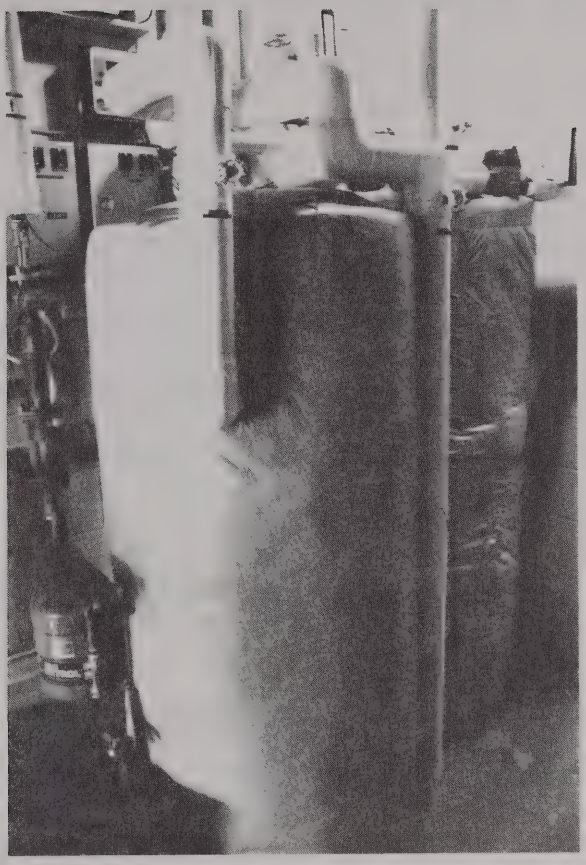
A. Piping - All system piping is copper and is connected as shown in the system schematic, page 36 (see Specifications, page 46, for details of piping types and sizes). The solar loop is a closed loop of 3/4" pipe. At the solar collectors, piping is connected by flexible rubber hoses that are resistant to chemical attack from the antifreeze fluid and reinforced with nylon fabric to withstand 200 psi and 400°F. All system piping whether external or internal to the rest area building is protected with an outer layer of standard white PVC and insulated with an inner layer of urethane foam having an R-value of greater

than 9. Photograph 5, page 23 shows this pipe insulation which was manufactured by Insultek Corporation, 82 Crestwood Road, Rockaway, New Jersey, 07866.

B. Valves - An automatic mixing valve is located just after the auxiliary storage tank (see schematic, page 36). This valve mixes cold supply water with the hot water exiting from the auxiliary storage tank so that the water enters the rest rooms at 110°F. In this way the domestic hot water is maintained at a safe temperature and hot water is conserved. This valve does most of its mixing in the summer when the water leaving the auxiliary tank can exceed 150°F due to solar heating. The automatic mixing valve has an external temperature adjustment, a maximum temperature and pressure of 200°F and 125 psig, and a 12 gallon per minute rating.

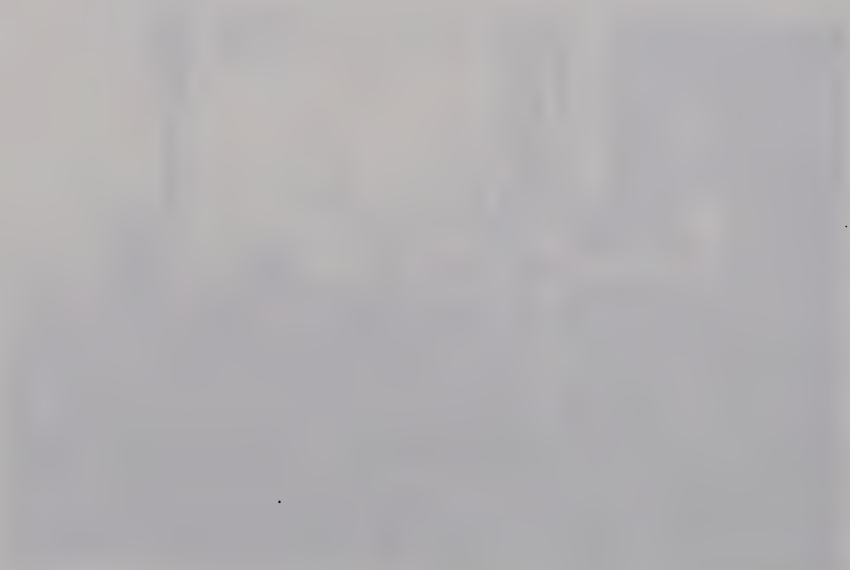
Pressure and temperature relief valves are located as shown in the system schematic to maintain safe operating conditions in the solar and domestic hot water loops. A 50 psi pressure relief valve is placed in the solar loop, and as mentioned each storage tank has a temperature and pressure relief valve which is set at 150 psi for the solar preheat tank and 125 psi for the auxiliary tank.

Gate, check, and drain valves are located as shown in the system schematic. The gate valves completely shut off water flow when closed and thus allow for flow control permitting by-passing of either the solar or auxiliary tanks. The check valves only permit water flow in the desired direction. Drain valves are placed in the solar loop to provide a means of draining or adding antifreeze solution; and in the domestic hot water loop, for removing water from the two storage tanks.



PHOTOGRAPH 4. WATER STORAGE TANKS

PHOTOGRAPH 5. PIPE INSULATION



All of the valves are standard good quality fittings available at most plumbing supply stores.

C. Other Fittings - A Solar Extrol Model S-15 expansion tank is located in the solar loop to accomodate the increased volume of the antifreeze solution as it is heated. The tank has a 2 gallon capacity and contains a diaphragm made of EPDM, a material compatible with the antifreeze fluid in the system. The maximum working pressure of the tank is 75 psi and the maximum operating temperature is 300°F. The expansion tank is made by Amtrol Inc., West Warwick, Rhode Island.

A Taco adjustable flow regulator was installed in the solar loop and set to allow a flow rate of the antifreeze fluid of 1.5 gallons per minute for efficient heat transfer. Flow rate is observed on a float type meter. The regulator, which limits water flow regardless of incoming pressure, is made by Taco Inc. (address given earlier).

An air vent, isolation flanges, and strainers were installed as shown on the system schematic. The air vent is located at the high point of the solar loop at the exit from the collector panels. This vent permits entrapped air to escape from the system. Isolation flanges are positioned on both sides of the circulating pump; accordingly, the pump can be repaired without having to drain and refill the entire system. One strainer is located in the solar loop; and one, in the DHW loop. They are positioned ahead of the intake side of the system monitoring flow meters and prevent these meters from becoming clogged with foreign material. These fittings are standard items widely available from plumbing suppliers.

MONITORING SYSTEM

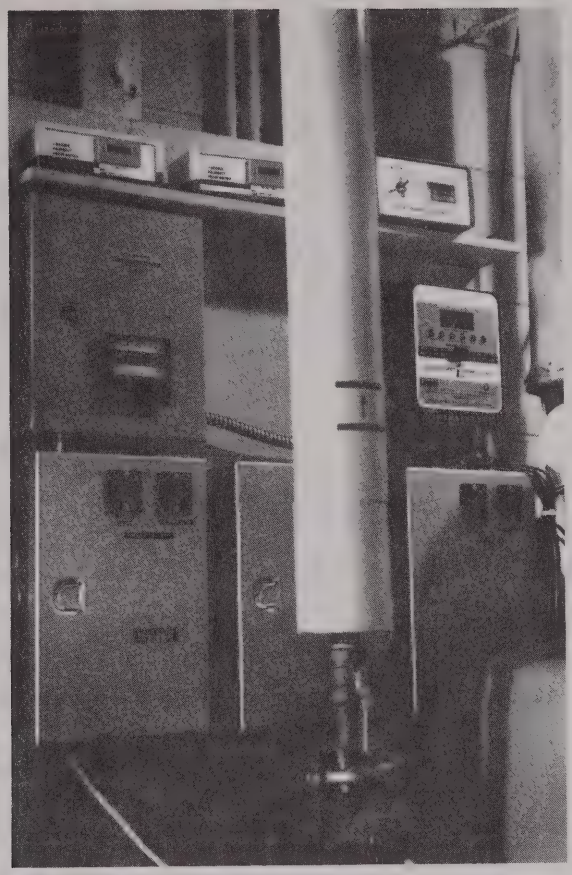
The monitoring equipment for the solar DHW system is described below. Solar radiation, thermal energy (BTU), electrical energy (kWh), temperature, pressure, fluid flow rate, and hours of operation are monitored through use of a pyranometer-integrator set, BTU meters, kilowatt-hour meters, thermistors and thermometers, a pressure gauge, flow meters and an hour meter. Some of the components of the monitoring system are shown in the background of Photograph 6, page 26. Starting in the upper left hand corner and proceeding clockwise are shown Kilowatt-hour Meters Nos. 1 & 2, solar radiation accumulating integrator, differential temperature controller, BTU Meters Nos. 3, 2, & 1, and the elapsed time hour meter.

Eppley Black and White Pyranometer (Model 8-48)

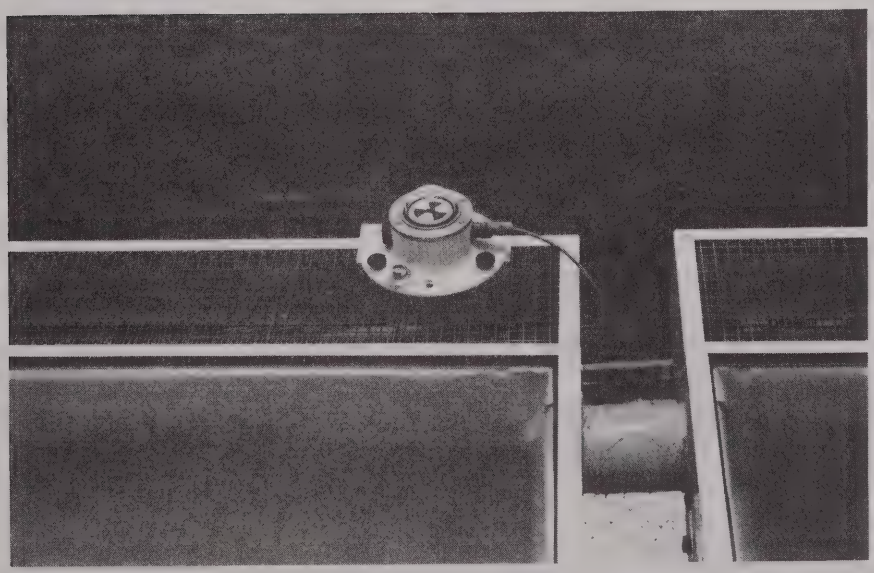
This pyranometer, which measures solar insolation in the plane of the solar collectors, is mounted as shown in Photograph 7, page 26. Made to National Weather Service specifications, it has precision ground optical glass which is transparent to wavelengths of 280 to 2800 nanometers (0.28 to 2.80 microns). Additional specifications for the pyranometer are given on page 47 of Appendix B. The output signal from this pyranometer is sent to the accumulating integrator described below. The black and white pyranometer is made by Eppley Laboratory, Inc., 12 Sheffield Avenue, Newport, Rhode Island 02840.

Accumulating Integrator

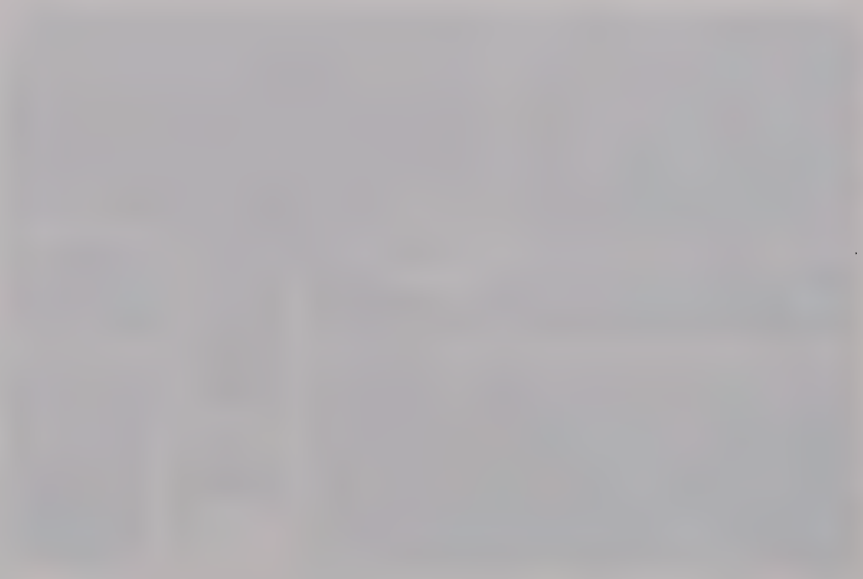
The Model 616-2 solid state integrator processes the input signal from the Eppley pyranometer and records the solar insolation on a 5-digit non-resettable counter which reads in BTU/ft^2 (British Thermal Units per square foot). Thus, the two instruments in conjunction provide monitoring of the total solar energy



PHOTOGRAPH 6. MONITORING EQUIPMENT



PHOTOGRAPH 7. BLACK & WHITE PYRANOMETER



incident in the plane of the collectors. Further specifications for the integrator, which is factory preset to match the pyranometer, are given on page 48 of Appendix B. The accumulating integrator was obtained from Science Associates, Box 230, 230 Nassau Street, Princeton, New Jersey, 08540.

BTU Meters

Three RS805 Series solid state BTU meters are used in the monitoring system. These meters measure BTUs by comparing inlet and outlet fluid temperatures, measuring flow rates, and electronically integrating the result. Therefore each BTU meter is connected to two thermistors and a flow meter as shown in the system schematic. Each meter has two non-resettable 6-digit electro-mechanical counters, one of which shows the accumulated BTU reading in kBTU and the other which shows the total gallons of water read by the flow meter. Two of the BTU meters (Nos. 2 & 3) monitor the domestic hot water loop and record the solar contribution to the domestic hot water heating load and the domestic hot water heating load demand, respectively. BTU Meter No. 1 monitors the solar loop and records the solar thermal energy supplied to the preheat storage tank. BTU Meter No. 1 is calibrated for water therefore the counts it registers must be adjusted to account for the fact that propylene glycol antifreeze solution flows in the solar loop.

The BTU meters are manufactured by the Rho Sigma Division of Watsco, Inc., 1800 W. Fourth Avenue, Hialeah, Florida 33010 and sold by Kent Meter Sales, Inc., P. O. Box 1852, Ocala, Florida 32678.

Flow Meters

There are three flow meters in the monitoring system. One monitors the flow rate in the solar loop; the other two, flow rates in the DHW loop. A Kent ESJ-Q hot water meter was installed in the solar loop. It is a single jet, inferential design meter which measures flow rates down to 1 gallon per minute, with normal operation up to 195°F. Two Kent C-700-FE cold water meters were installed in the cold water supply section of the DHW loop. They are polymer case, positive displacement type meters that handle flows to 30 gallons per minute at 150 psi and temperatures up to 125°F. The three flow meters have pulsed outputs which are compatible with the BTU meters to which they are connected. The flow meters are available from Kent Meter Sales, Inc. (address given above).

Kilowatt-hour Meters

Two J Series kilowatt-hour meters monitor electrical energy consumption. Kilowatt-hour Meter No. 1, which monitors the electrical energy consumed by the solar DHW system, i.e., the pump and differential temperature controller, is a low power unit (500 watts RMS) having nominal maximum ratings of 120 VAC and 4A AC RMS. Kilowatt-hour Meter No. 2, which monitors the electrical energy consumed by the heating element of the auxiliary storage tank, is a higher power 6 kW unit which has nominal maximum ratings of 240 VAC and 25A AC RMS. Both meters have electromechanical digital readout -- Meter No. 1 has a resolution of 0.01 kWh; Meter No. 2, 0.1 kWh. The kilowatt-hour meters are made by Spectrex Co., Box 2098, Reston, Virginia 22090.

Thermistors and Thermometers

The thermistors and thermometers used in the solar DHW system are standard sensors. The thermistors, which have an accuracy of ±1°F from 32° to 212°F,

sense temperatures for the differential temperature controller and the BTU meters. Three standard pipe thermometers provide visual indication of the temperature of the cold water input, the hot water out of the electric auxiliary tank, and the hot water to the wash rooms. Locations of the thermistors and thermometers are shown in the system schematic on page 36.

Pressure Gauge

A standard pressure gauge was installed in the solar loop to monitor the pressure of the antifreeze fluid. The pressure gauge indicates pounds per square inch (psi).

Elapsed Time Hour Meter

A Simpson AC hour meter (with non-resettable readout) is connected to the differential temperature controller to indicate elapsed time. It reads the "on" time of the circulating pump.

PROBLEMS IN INSTALLATION

The following problems were noted either during routine inspection of ongoing assembly or during the working test period. None of the problems were considered serious. Repair of Kilowatt-hour Meter No. 2, however, delayed acceptance of the system by about two weeks.

Leak in Roof

After installing one solar panel roof support curb, the contractor cut into the built-up roof to install the second support curb. The built-up roof, which consists of 2-1/2 inches of treated fiber board, sits directly on the building's concrete roof. At the end of the day the contractor left without covering the

cutout portion of the roof. Later that night it rained and water seeped into cutout portions of built-up roofing. The water travelled along the concrete roof to bolts that secured the installed support curb to the concrete. It then ran down the bolts, through the concrete roof and into the men's room. There was no significant damage, and after the second support curb was installed, there was no further leakage.

Misplaced Strainer in Solar Loop

Before the Kent hot water meter was received a strainer was installed in the solar loop. When the Kent hot water meter arrived, there was no room directly after the strainer to accommodate the meter. Accordingly the meter was installed in another part of the solar loop, and the strainer was removed and placed next to the input side of the meter.

Inaccurate Kilowatt-hour Meter

Kilowatt-hour Meter No. 2, which monitors the electrical energy used by the auxiliary tank, showed erroneous readings and was sent back to the factory for repair. It was recalibrated and returned in proper working order.

Improperly Set BTU Meter

BTU Meter No. 1, which monitors the heat supplied to the solar preheat storage tank, read 2 gallons for every 1 gallon through Hot Water Flow Meter No. 1. It was manually reset to read properly by adjusting a switch.

INSPECTION AND TESTING

Construction of the solar DHW system took place in August and September of 1982. Over this period, NJDOT personnel monitored and inspected the

installation on a daily basis since DOT, as the system designer, was most qualified to perform these tasks. The system was installed in accordance with the uniform construction code of New Jersey and Harding Township ordinances. Before the start of a working test period, the subcontractor leak tested the piping at a pressure of more than 1-1/2 times operating pressure.

A working test period began on September 27, 1982 -- when the solar DHW system was essentially completed and operating with all monitoring equipment installed -- and lasted for more than a month. During this time the system was run continuously and operation of the entire system was checked including automatic features and monitoring equipment. The subcontractor made final adjustment and repairs to the equipment to bring the system in line with the specifications and acceptable to the DOT inspector. In addition, the subcontractor instructed DOT's operating personnel in the operation and maintenance of the system and provided a system schematic and a guide for operation and maintenance which is included as Appendix D, pages 66 & 67. This guide describes the procedures for checking system operation, draining and filling the system with antifreeze, and maintenance and servicing. Also valves, meters, and gauges were labeled by the subcontractor so that DOT could more easily control and monitor the system.

Final inspection and acceptance of the solar DHW installation as complete by NJDOT and Department of Treasury personnel occurred on November 8, 1982. The one year period of system monitoring also began on this date as well as all warranties. A one year warranty against defects in materials and workmanship of all components of the solar DHW system, a five year warranty against collector absorber plate leakage, and a five year warranty against losing more

than 10% optical efficiency of collector cover plate and absorber plate coating were issued to the State by the prime contractor. Also the State was given any manufacturers' written warranties on system components.

COST OF INSTALLATION

There were no change orders to the installation contract thus the solar DHW system with the monitoring system was completed for the bid price of $16,745. Of this amount approximately $4,800 was expended for the monitoring system; approximately $12,000, for the solar system. This bid price included the cost of all materials, equipment, labor and testing. Payment was contingent on acceptance by the State of the completed system. The installation contract contained a penalty clause regarding late completion but no damages were claimed by the State.

MONITORING AND EVALUATION OF THE SOLAR DHW SYSTEM

MONITORING

The solar domestic hot water system is being monitored for one year starting on November 8, 1982. Routine monitoring is done weekly; the data collected includes solar radiation integrator, BTU meter, kilowatt-hour meter, thermistor, thermometer, and elapsed time meter readings. A weekly raw data sheet is shown as Figure C-2, page 63 of the system Monitoring Plan which is Appendix C. From this raw data, system performance indicators are calculated weekly and monthly. The twelve performance indicators are listed on page 62 of the Monitoring Plan. They include incident solar radiation, solar thermal energy supplied to the preheat storage tank, domestic hot water heating demand, solar and auxiliary thermal contributions to this demand, heat losses from the solar preheat and auxiliary storage tanks, operating electrical energy for the solar and auxiliary systems, and the electricity saved by the solar DHW system. The Monitoring Plan explains the performance indicators and illustrates how they are calculated. Monthly reports are prepared and submitted to the FHWA; they list and discuss monthly totals for the performance indicators and report on the operational status of the system, encompassing system downtime, and maintenance and repair. The monthlies also include the percentage of the incident solar radiation supplied to the preheat tank, the percentage of the total hot water heating demand provided by solar means, and the monthly dollar savings for electricity replaced.

EVALUATION

Based on the results of one year's monitoring, the solar DHW system at the Harding Township rest area will be evaluated for performance and cost. Yearly totals for the twelve performance indicators mentioned will be developed;

accordingly, the percentage of the hot water heating load for the year supplied by solar means will be determined, and the year's electricity savings will be calculated. Performance of the system in terms of operational status and downtime, and the need for maintenance and repair will be evaluated. Costs associated with this maintenance and repair work will be reported and the estimated dollar savings due to the electricity replaced by solar energy will be calculated for the year. With regard to system downtime and problems with system components, causes will be identified and solutions given.

A final report will be prepared which will contain the results of the overall system evaluation including performance and cost information. This report will also include a description of the basic solar domestic hot water system (collector size and orientation, storage tank capacity, back-up system, etc.) and of the rest area facility; information on designer, contractor, climate, etc.; operational experience, including maintenance and servicing history; and an overall owner evaluation. Furthermore, overall economic feasibility of the solar DHW system will be evaluated by the inclusion of a revised 20 year life cycle cost analysis which will reflect actual equipment and installation costs and current electricity costs.

APPENDICES

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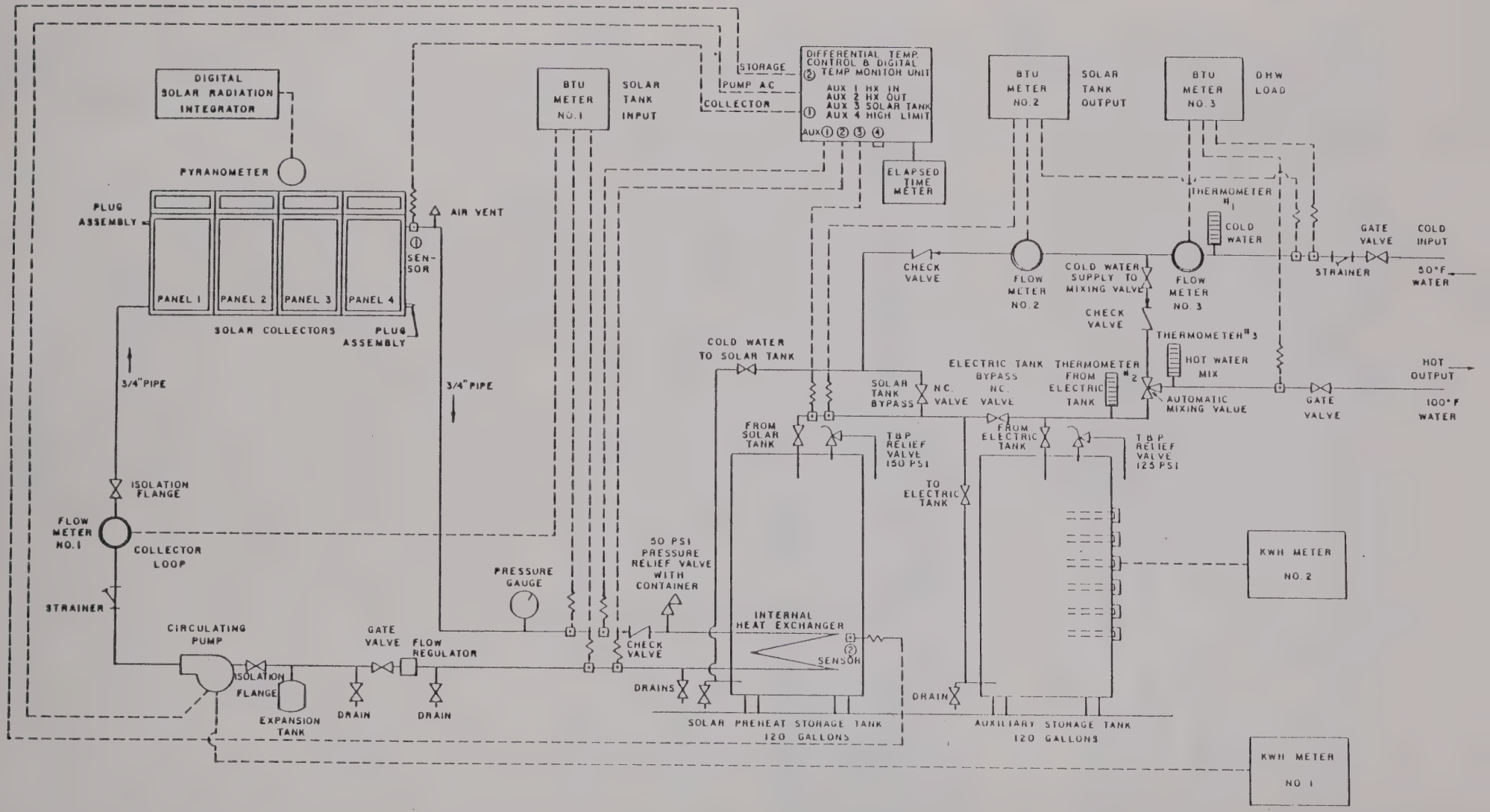
B. Specifications for Harding Township Rest Area Solar DHW System 37

C Monitoring Plan 52

D. Guide for Operation and Maintenance 66



APPENDIX A. SOLAR DOMESTIC HOT WATER SYSTEM

(AS-BUILT SCHEMATIC)

NOT TO SCALE

APPENDIX B

SPECIFICATIONS

FOR

ROUTE 287 SECTION 8L

INSTALLATION OF A SOLAR DOMESTIC HOT WATER SYSTEM

HARDING TOWNSHIP REST AREA, MORRIS COUNTY

FEDERAL PROJECT NO. DOT-FH-15-386

1.0 DESCRIPTION

This specification covers the manufacture, workmanship, installation, inspection, testing and shipping of a complete solar retrofit domestic hot water system. The system shall include but not be limited to the following components and items: solar collectors, over-temperature heat rejection system, heat transfer fluid, circulating pump, hot water storage tank, temperature controllers, control valves, piping, roof mounting hardware and monitoring equipment.

Operating temperature ranges, flow rates, equipment rating and quality shall be as stated herein or on the drawings.

2.0 OPERATING CONDITIONS

The system and all of its components shall be suitable for operation under the following conditions unless otherwise stated herein or on the drawings.

2.1 Any non-metallic materials contained in the system shall be suitable for operation within temperature ranges from -29°F to 200°F.

2.2 Ambient temperatures vary from -20°F to 120°F. The average ambient winter temperature is 36.8°F.

2.3 Solar loop pressure shall be 25 psi under standard operating conditions at 100°F with 40°F ambient temperatures.

2.4 Potable water supply operating pressure is approximately 55 psi.

2.5 Design inlet temperature of the potable water supply is 50°F. The outlet temperature shall be 100°F.

2.6 Average hot water demand shall be 240 gallons per day ((.6 gallons/person/day) x 400 tourists).

3.0 SOLAR COLLECTORS

3.1 The solar collectors shall be designed to absorb solar radiation and transfer heat to the circulating fluid. The solar collectors shall be flat plate copper collectors, liquid cooled

with single glazing and a selective absorber coating. Four collector panels shall be required with a net cover plate aperture of 21 sq. ft. or greater per collector.

3.2 The solar collectors consisting of a cover plate, absorber, insulation, piping, fittings, over-temperature heat rejection device, and collector case shall be assembled in a suitable manner to maintain the thermal performance and structural integrity for a service life of at least 15 years. Bidders shall submit information regarding any tests that have been performed to determine service life of collector components. The collectors shall be warranted for at least one year from date of system acceptance against failure of any component. The collector shall be housed to withstand the effects of rain, sleet, snow, dust and windloads of 120 mph.

3.3 All parts of the collector shall be easily replaced in the field. This includes the cover plate, absorber, insulation, piping, fittings, over-temperature heat rejection system and collector case. During the 12 month warranty period the supplier shall be responsible for replacement of components that have failed. Condensation of out-gassing material on the cover plates shall be considered to be component failure and will require that the responsible material or component and the glass cover be replaced.

3.4 The collector case shall be aluminum with white baked polyester enamel. Dimensions, 44-1/2" wide, 72-3/4" high. The cover for pipe connections shall be 5-1/8" high and 44-1/2" wide. The over-temperature heat rejection panel shall be 8" high and 44-1/2" wide.

3.5 The cover plate shall be tempered glass 3/16" thick of low iron content. The net aperture of the collector cover plate shall be 21.1 sq. ft. The cover plate shall be designed to withstand a windload of 120 mph. The cover plate shall be sealed with a waterproof gasket and an aluminum glazing strip. The glass shall be clean and free of cracks, chips or other obvious imperfections and suitably mounted to withstand thermal expansions and contractions.

3.6 Insulation shall be high temperature isocyanurate foamed in place 1.5" on bottom, 1" on sides of collector. Density = 2.5 lb/ft^3. Moisture barrier is to be a polyvinyl fluoride

membrane. Thermal conductivity K = 0.13 BTU IN/HR FT^2 ^oF @ 70^oF. Flame spread rating of all insulation = 25 (ASTM/E-84).

3.7 The absorber is to be copper plate with parallel 1/4" nominal copper tubing with a black chrome selective coating of pre-baked high temperature black velvet paint. The internal manifold system shall have four external 1" type M beaded copper tube connections. Connections between collectors shall be made with clamps and flexible hoses. All copper joints shall be silver brazed.

3.8 Mounting provisions shall include two 1/4-20 threaded holes in each corner for securing mounting channels or other mounting hardware.

3.9 The fluid system shall have a capacity of 0.45 gallons. The system operating pressure shall be 25 psi with a 50 psi pressure relief valve for protection.

3.10 The collector fluid shall have the following flow rate-pressure drop.

Flow Rate	Pressure Drop (1 collector - 10 collectors)
0.3 GPM (minimum)	0.080 - 0.138 psig 140^oF
0.5 GPM (nominal)	0.135 - 0.271 psig 140^oF
0.7 GPM (maximum)	0.188 - 0.485 psig 140^oF

3.11 All metal surfaces in contact with antifreeze fluid shall be copper or brass. All gaskets, seals, and other materials in contact with antifreeze fluid shall be compatible with propylene glycol antifreeze mixture.

3.12 All fittings shall be standard size and type.

3.13 Collectors shall be capable of being completely drained and shall have no spaces in the fluid passages which can entrap air.

3.14 The collector panels shall be tilted at an angle of 30^o (40^o LAT - 10^o). The collector AZIMUTH shall be true south.

3.15 Collectors shall have been performance tested using performance test specifications ASHRAE 93-77. Bidders shall submit the test results with their proposal and shop drawings.

3.16 The collector shall be capable of withstanding its own stagnation temperature without degradation of materials, out-gassing, loss of fluid or glass breakage. It shall be capable of withstanding fluid pressures of 150 psi.

3.17 The instantaneous efficiency of the collector shall be at least equal to or greater than that shown on the following curve when plotted against collector average inlet temperature, ^{o}F, ambient air temperature, ^{o}F, and incident insulation, $BTU/HR\text{-}FT^2$. (See Figure B-1, page 42.)

3.18 Individual collectors shall not exceed a weight of 200 lbs. filled.

3.19 The collector panels shall be elevated 12" above the roof for snow clearance.

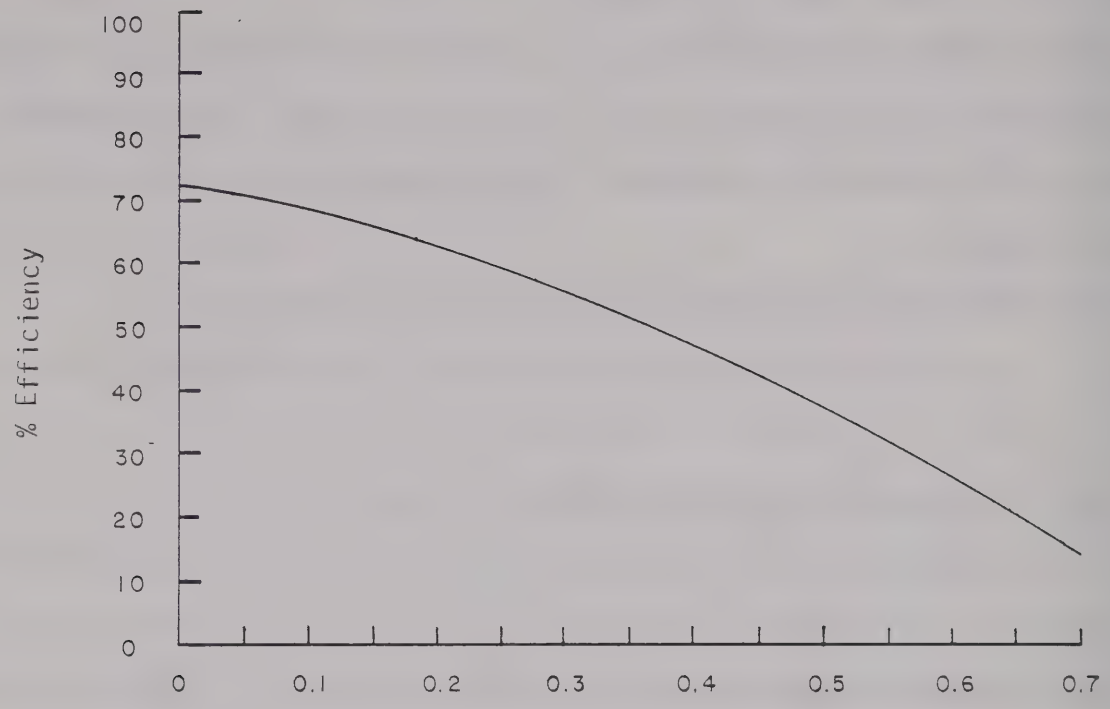
4.0 OVER-TEMPERATURE HEAT REJECTION EQUIPMENT

4.1 Over-temperature protection such as heat rejection panels shall be incorporated in the design of the solar collectors (see Section 3.4) to automatically control the heat transfer fluid temperature to acceptable levels. This shall be designed for high solar insolation, no demand, stagnation conditions, or during system downtime when high heat levels (325 ^{o} - 400^{o}F) may exceed the maximum operating temperature limit of the heat transfer fluid, thereby risking irreversible degradation of the fluid. A thermal mechanically activated valve on each collector shall open when the temperature of the heat transfer fluid in each collector reaches 225^{o}F allowing heat from the fluid to be dissipated to the atmosphere through the heat rejection panels.

5.0 ANTIFREEZE HEAT TRANSFER FLUID

5.1 The antifreeze heat transfer fluid shall be a non-toxic non-flammable propylene glycol solution. The fluid shall be capable of withstanding stagnation temperatures up to 350^{o}F without chemical degradation.

5.2 The antifreeze heat transfer fluid shall be 52% by weight. The specific heat of the fluid at 100^{o}F shall be 0.854 BTU/LB-Degree Fahrenheit.



T_i = collector inlet average temperature, °F

T_a = ambient air temperature, °F

I = solar insolation, BTU/HR-FT^2

NOTE: Bidder shall show project solar collector efficiency curve.

Figure B-1. Collector Thermal Characteristic

5.3 The antifreeze heat transfer fluid shall protect the solar system from freezing down to temperatures of -30°F.

6.0 CIRCULATING PUMP

6.1 The circulating pump shall be capable of handling the pressure drop from Flowmeter No. 1, while delivering sufficient flow with a 16 ft. head.

6.2 All pump components exposed to the propylene glycol solution shall be constructed of non-corroding materials.

6.3 All gaskets should be designed to operate at extreme temperatures without shrinking or swelling.

6.4 The pump shall have isolation flanges provided on both sides of the pump.

6.5 The pump shall have a warranty period of not less than 12 months.

7.0 HOT WATER STORAGE TANK

7.1 The new storage tank shall have a storage capacity of 120 gallons.

7.2 The tank shall be constructed of heavy duty steel with a stone lining of 1/2 inch thickness of seamless hydraulic stone.

7.3 A temperature and pressure relief valve shall be top mounted to protect the system under high temperatures (200°F) and high pressure (150 psi).

7.4 The hot water outlet pipe shall be designed to keep heated water inside the tank thus resulting in lower operating costs.

7.5 The storage tank shall be approximately 69 inches high and 28 inches in diameter.

7.6 A water diffuser shall be incorporated to introduce cold water in a gentle pattern at the bottom of the tank.

7.7 All fittings exposed to water shall be bronze.

7.8 The heat exchanger shall be made of copper and located in the stored water. It shall be 40 sq. ft. and braced with nonferrous angle bar welded to the tank side.

7.9 The storage tank shall be insulated with 4 inch thickness closed cell foam with an R-value = 11.

7.10 A thermal insulating blanket shall be provided for the existing 120 gallon hot water storage tank. The insulating blanket and the existing tank insulation shall have a combined R-value no less than R-11.

7.11 The lowest heating element in the existing 120 gallon hot water storage tank shall be locked out so that only the upper electric heating element is operable.

8.0 DIFFERENTIAL TEMPERATURE CONTROLLER AND ELAPSED TIME INDICATOR

8.1 The differential temperature controller shall provide automatic control of the solar loop circulating pump. The controller shall have a solid state differential on/off switch which is capable of controlling all cycles in the closed loop heat transfer system.

8.2 The controller input shall be provided by two compatible temperature sensors, one welded on the side of the storage tank and the other welded on the collector absorber plate as close to the outlet of the collector tubing as possible. The controller shall activate the circulating pump when $\Delta T \geq 20^{\circ}F$. The controller shall turn off the circulating pump when $\Delta T \leq 5^{\circ}F$.

8.3 The differential temperature controller shall operate on 120V AC, 60HZ.

8.4 The controller shall have a storage high temperature limiter to prevent storage temperatures from exceeding $180^{\circ}F$.

8.5 The differential temperature controller shall have a warranty period of not less than one year.

8.6 The controller shall monitor collector, storage and four additional temperature locations as indicated on the system schematic drawing. The six temperatures shall be sequenced by depressing a sensor select button and displayed by an LED digital readout. The display shall flash if the temperature being monitored is outside the range $32^{\circ}F$ to $212^{\circ}F$. Temperature sensors shall be thermistor type and screw-in for standard 1/2" NPT.

8.7 The elapsed time indicator shall be an AC hour meter connected to read the operating "on" time of the circulating pump in the solar collector loop. The read-out shall be non-resettable to 99,999.9 hours with contrasting tenths. The meter shall contain a quiet synchronous motor with epicyclic stepdown gearing.

9.0 VALVES, GAUGES, AIR VENTS, STRAINERS, DRAINS, AND REGULATORS

9.1 These components shall be as shown on the drawings.

9.2 The mixing valve shall be a bimetal thermally activated valve.

9.3 The pressure relief valves in the solar loop and the potable water supply shall be located to prevent scalding of visitors and maintenance personnel. A fluid container shall be provided at the pressure relief fluid outlet of the solar loop so that any loss of antifreeze fluid can be detected.

9.4 The expansion tank shall have a two gallon capacity.

9.5 The flow regulator shall limit the flow in the solar loop to provide maximum heat transfer from the collector panels to the heat transfer fluid.

10.0 SYSTEM PIPING, HOSES, CLAMPS AND PIPE HANGERS

10.1 Flexible silicone rubber hoses shall connect supply and return manifolds of adjacent collectors, and shall also join distribution piping, close off plug assemblies, relief valves, vents and other fittings to the collectors. The hoses shall allow for thermal expansion and contraction and absorb any lineal mounting variations between collectors. They shall be resistant to chemical attack from antifreeze fluids and comply with FDA regulations, Section 177-2600. Hoses shall be reinforced with three ply nylon fabric and have 200 psi minimum burst pressure at 400^{o}F.

10.2 The appropriate copper connector shall be used to connect the 3/4" diameter copper piping in the solar loop to the flexible silicone rubber hose which connects to the 1 1/8" collector inlet and outlet connections.

10.3 Hose clamps shall be of the worm drive bank type and shall be designed to secure the silicone rubber hose to the piping. The clamp shall be of stainless steel with a stainless steel liner to prevent extrusion of the silicone rubber hose through the band notch. For proper sealing, the worm drive screw shall have a torque of 40 inch pounds. The hose clamp shall have a corrosion resistant worm drive.

10.4 All external copper piping shall be protected with an outer casing of standard white PVC and insulated with an inner layer of urethane foam having a minimum R-value of 8.

10.5 Solar loop piping shall be 3/4" Type M copper piping.

10.6 Potable water piping shall be Type L copper piping and the same size as existing potable water piping.

10.7 Piping between collectors shall be flexible silicone rubber hose.

10.8 Metal pipe hanger straps shall be insulated from the system piping by fully enclosing the pipe insulation.

10.9 All piping below the building roofline shall be insulated with a casing of urethane foam insulation having a minimum R-value of 8.

11.0 ROOF MOUNTING HARDWARE

11.1 Roof anchors and mounting frame shall be strong enough to withstand winds up to 120 mph.

11.2 The roof mounted collector frame shall be located as shown on the building roof plan. The contractor shall take special precautions when drilling roof holes to ensure that penetrations are made through the roof bar joists. The contractor shall be responsible for filling, sealing, and waterproofing any and all holes drilled in improper locations at no cost to the State.

11.3 All connections through the roof shall be waterproof.

11.4 All pipe and electrical conduit penetrations shall be flashed and sealed using a pipe seal assembly as manufactured by the Pate Co., Broadview, Illinois 60153 or equivalent. The

pipe seal assembly shall consist of a spun aluminum base having a minimum five inch roof surface flange and a stepped neoprene rubber boot to be secured to the base and the pipe with adjustable stainless steel clamps. A waterproof silicone sealer shall be applied over the neoprene rubber boot and stainless steel clamps. Mastic shall be applied between the built-up roofing and the spun aluminum base. Mastic shall also be applied between the aluminum base and the roof insulation membrane.

A detail of the pipe seal assembly and roof penetration is shown on the plans. The location of pipe and electrical conduit penetrations through the roof shall be approved by the State before such penetrations are made.

11.5 The solar collector framing shall be anchored to two parallel prefabricated support curbs as shown on the plans. The curb shall be the type designed for use on a concrete deck with rigid insulation. The integral raised cant shall be fabricated to match the thickness of the deck insulation and provide a full canted section above the roof line. The steel support, base plate and counter flashing cover shall be 14 gauge galvanized steel. The wood nailer shall be factory cut and pressure treated by wolmanizing. Acceptable manufacturers are ThyCurb Div. of Thybar Corp., S&L Manufacturing Co. and the Pate Co.

11.6 The collector framing shall be 1-5/8" x 1-5/8" pre-galvanized slotted U channel roll formed from 12 gauge (.105" thick) low carbon strip steel. One side of the channel shall have a continuous slot with inturned clamping ridges. Secure attachments may be made to the framing member with the use of hardened, toothed slotted nuts which engage the clamping ridges.

11.7 All parts, screws and nuts shall be galvanized.

11.8 All installation shall be according to good roofing practice and manufacturers' instructions.

12.0 MONITORING EQUIPMENT

12.1 Pyranometer - The pyranometer for the measurement of solar insolation in the plane of the collectors shall be an Eppley Black and White made to National Weather Service

Specification No. A105-SP001, or equivalent. Temperature compensations shall be ± 1.5% over the range from -20° to 40°C. Spectral response shall be in the wavelength range of 280 to 2800 nanometers (0.28 to 2.80 microns). The orientation of the pyranometer shall have no effect on its performance. Associated mounting hardware shall be provided. The pyranometer shall be mounted in the plane of the solar collectors.

12.2 Accumulating Integrator - The accumulating integrator for the recording of solar insolation shall be a Science Associates, Inc. No. 666A or equivalent. The integrator shall be of solid state circuitry construction for operation on 115 volts ac, 50/60 hertz. The integrator shall include a 5-digit non-resettable counter scaled and calibrated in kBTU/ft ^{2} (1000 BTU per square foot).

12.3 BTU Measurement System - Three BTU meters shall record solar thermal energy stored in the preheat storage tank, solar thermal contribution to the domestic hot water heating load, and domestic hot water heating load demand. The location of the flowmeters and temperature sensors for the BTU meters shall be as shown on the accompanying drawing. The BTU meters shall be Rho Sigma RS805 or equivalent. Each BTU meter shall have non-resettable digital displays of kBTU (1000 BTU) and gallons. The BTU meters shall be of solid state circuitry construction, power input 115 volts AC, 50/60 hertz, and overall system accuracy ± 1.78% of full scale.

The fluid in the collector loop will be a non-toxic propylene glycol solution 52% by weight. The specific heat of the fluid at 100°F is 0.854 BTU/LB-Degree Fahrenheit. Since normally BTU meters are calibrated for water with a specific heat of 1 BTU/LB-Degree Fahrenheit, BTU Meter No. 1 in the collector loop shall either be calibrated for the heat transfer fluid or shall be supplied with a conversion table to convert the reading on the BTU meter to correct values.

Flow Meter No. 1 in the collector loop shall be a Kent Model KSR-W, 3/4 inch hot water meter or equivalent. The flow meter shall be capable of nominal operation in the 195 to 200°F range and shall be capable of withstanding peak temperatures of 230°F. The flow meter shall

be capable of operating at a flow rate between 0.22 to 22 gallons per minute. The pulse output of the flow meter shall be compatible with the BTU meter.

Flow Meters No. 2 and No. 3 in the cold water lines shall be Kent Model C-7700-FE, 3/4 inch cold water meters or equivalent. The flow meters shall be capable of operating at a flow rate between 0.25 to 30 gallons per minute and at temperatures to 130°F. The pulse output of the flow meters shall be compatible with the BTU meters.

The temperature sensors for the BTU meters shall be thermistor type and screw-in for 1/2" NPT. Accuracy of the thermistors shall be ±1°F from 32° to 212°F.

12.4 Kilowatt-hour Recorders - Two kilowatt-hour recorders shall be installed to monitor energy consumption. One shall record the energy consumed by the existing electric hot water tank. The other shall record the energy consumed by the solar system; i.e., the pump and differential temperature controller.

13.0 LABELING

13.1 All components shall be clearly labeled including valves, meters and gauges so that the system can be controlled and monitored.

13.2 The contractor shall supply a system diagram and a system description located in an visible position adjacent to the equipment detailing the proper start up, shut down, draining, filling, servicing and maintenance procedures for the system and components.

13.3 The contractor shall demonstrate that the system and controls are operating as designed.

14.0 INSTALLATION

14.1 The system shall be installed in accordance with the uniform construction code of New Jersey and Harding Township ordinances.

14.2 The location of all system components and roof penetrations shall be approved by the State before their installation is performed.

15.0 SHIPPING

15.1 System components shall be securely mounted and packaged for shipping to the job site. Adequate protection must be provided for threads, flanges, and protruding parts. All threaded, flanged or open connections shall be fitted with an adequate cover.

16.0 INSPECTION AND TESTING

16.1 All system components shall be inspected by the contracting officer before final acceptance. In the event of damage, the vendor shall immediately make all repairs and replacements necessary for the approval of the contracting officer at no additional cost.

16.2 After the system has been completely installed and is ready for operation, the system shall be filled with a solution of one pound of trisodium phosphate for each 50 gallons of water in the syste, After filling, the system shall be vented and circulated for three hours, then completely drained and flushed with fresh water. The solar system shall then be filled with the antifreeze heat transfer fluid.

The contractor shall pressure and leak test all piping before installing insulation and outer casing. The testing pressure shall be a minimum of 1½ times operating pressure.

The system shall then be operated for a period of four continuous days to demonstrate and test the system. During this time, adjustments and repairs shall be made to the equipment so that it is in perfect condition and acceptable to the Engineer. During the test period, the contractor's representatives shall instruct the State's operating personnel in the operation and maintenance of the system. Any required instruction shall be provided by the representatives at this time. The scheduling of the operational and instructional period shall be coordinated with the Engineer.

The contractor shall issue to the State a written one year warranty against defects in materials and workmanship of all components of the solar domestic hot water system. Any part of the installation or component parts determined to be defective shall be replaced at the sole cost of the contractor. The solar collector absorber plates shall be warranted against

leakage for a period of five years, and the window and absorber plate coating shall be warranted against losing more than a total of 10% optical efficiency for a period of five years. In addition the contractors shall supply to the State any manufacturers' written warranties on component parts of the system and monitoring equipment.

17.0 QUANTITY AND PAYMENT

Payment will be made at the lump sum price bid in the proposal for Item No. 1, "Solar Domestic Hot Water Systems," and Item No. 2, "Monitoring System," which price shall include all materials, components, equipment, labor, and testing. Payment will be made upon acceptance by the Engineer of all work performed by the Contractor in accordance with the plans and specifications or as directed by the Engineer; upon receipt of all warranties on equipment, materials, and workmanship; upon passing the operational testing period; and upon receipt of a properly completed invoice form with accompanying back-up.

APPENDIX C

MONITORING PLAN

for the

Solar Domestic Hot Water

System in the Harding

Rest Area Building, I-287

New Jersey Department of Transportation

1035 Parkway Avenue

Trenton, New Jersey

Revised May 1983

The solar domestic hot water system in the Harding rest area building will be monitored routinely and a report will be submitted to the FHWA on a monthly basis for one year after system start up. System performance will be monitored using the instrumentation shown on the system schematic diagram.* The main components are a pyranometer, BTU meters and kilowatt-hour meters. The following indicators of system performance will be determined from the monitoring data each month.

- Insolation incident in the plane of the collectors
- Solar thermal energy supplied to the preheat storage tank
- Overall efficiency in supplying solar energy
- Domestic hot water heating load demand
- Solar thermal contribution to the domestic hot water heating load
- Heat loss from preheat storage tank
- Auxiliary thermal contribution to the domestic hot water heating load
- Heat loss from auxiliary tank and associated piping
- Operating electrical energy for the auxiliary system
- Percent solar contribution to the domestic hot water heating load
- Operating electrical energy for the solar energy system
- Electricity saved

In addition to the indicators of system performance listed above a record of maintenance and repair work with associated costs will be kept. The operational status of the solar system and monitoring system will be reported monthly along with system down time.

Below is a more detailed explanation of the system performance indicators to be monitored.

Insolation incident in the plane of the collectors, E_{IN} - A pyranometer measuring solar energy in the wavelength from 280 to 2800

*See page 65.

nanometers (.28 to 2.80 microns) will be mounted in the plane of the solar collectors. An accumulating integrator connected to the pyranometer will read solar insolation in units of BTU per square foot. The net collector aperature is 21.1 square feet for one collector and 84.4 square feet for four collectors. Therefore, multiplying the accumulating integrator reading for a specific monitoring period times 84.4 square feet will yield the total solar insolation incident in the plane of the collectors, E_{IN}, in BTU.

Solar thermal energy supplied to the preheat storage tank, E_S - BTU

meter #1, as shown on the accompanying schematic drawing, will monitor the heat being supplied to the preheat storage tank. The input and output temperatures to the preheat storage tank of the propylene glycol solution in the collector loop are monitored by two thermistors. The flow is monitored by flow meter #1, a hot water meter with a pulsed output. The circuitry in the BTU meter multiplies the difference in output and input temperature by the flow rate of the heat transfer fluid and integrates the product over time. The relationship for heat flow is shown below:

$$Q = k \int_0^t \dot{m}(T_2-T_1)\, dt$$

where,

Q = heat transferred (BTU)

k = specific heat of heat transfer fluid (BTU/gal/^oF)

$\dot{m}$ = flow rate of fluid (gal/min)

T_2= output temperature (^oF)

T_1= input temperature (^oF)

The BTU meter used is calibrated for water with a specific heat of 8.33 BTU/gal/^oF or 1 BTU/lb/^oF. The specific heat of the propylene

glycol solution (52% by weight) is 0.854 BTU/lb/^{o}F and the specific gravity is 1.05. Therefore the reading on the accumulating digital display of the BTU meter must be multiplied by 0.854 X 1.05 = 0.897 to obtain the correct amount of solar thermal energy supplied to the preheat storage tank. The BTU meter reads in 1000s of BTUs.

Overall efficiency in supplying solar energy, eff_{OA} - The overall efficiency in supplying solar energy can then be simply expressed as:

$$eff_{OA} = \frac{E_S}{E_{IN}} \times 100$$

where,

eff_{OA} = overall efficiency in supplying solar energy (%)

E_S = solar thermal energy supplied to the preheat storage tank (kBTU)

E_{IN} = insolation incident in the plane of the collectors (kBTU)

The difference between the insolation incident in the plane of the collectors and the solar thermal energy supplied to the preheat storage tank will be the amount of thermal energy lost from piping between the collectors and the preheat storage tank plus the amount lost due to collector efficiency. The collector efficiency can therefore be expressed as:

$$eff_C = \frac{E_S + Q_{P.\ Loss}}{E_{IN}} \times 100$$

where,

eff_C = collector efficiency (%)

E_S = solar thermal energy supplied to the preheat storage tank (kBTU)

$Q_{P.\ Loss}$ = thermal energy lost from piping between collectors and preheat storage tank (kBTU)

E_{IN} = insolation incident in the plane of the collectors (kBTU)

Since $Q_{P.\ Loss}$ will not be known for this system, collector efficiency will not be calculated.

Domestic hot water heating load demand, E_D - The domestic hot water heating load demand will be read directly from BTU meter #3 in 1000s of BTUs. The cold water flow meter #3 is located in the cold water supply with the two thermistors monitoring the cold water input and the domestic hot water output.

Solar thermal contribution to the domestic hot water heating load, E_{SH} - BTU meter #2 will read the solar thermal contribution to the domestic hot water heating load in 1000s of BTUs. The cold water flow meter #2 is located in the cold water supply to the preheat storage tank with the two thermistors monitoring the cold water input and the preheated water output.

Heat loss from the preheat storage tank, $Q_{S.T.\ Loss}$ - The heat loss from the preheat storage tank can be expressed as:

$$Q_{S.T.\ Loss} = E_S - E_{SH} - E_{\triangle TSolar}$$

where,

$Q_{S.T.\ Loss}$ = heat loss from preheat storage tank (kBTU)

E_S = solar thermal energy supplied to the preheat storage tank (kBTU)

E_{SH} = solar thermal contribution to the domestic hot water heating load (kBTU)

$E_{\triangle TSolar}$ = difference in heat stored in solar preheat tank at times of meter readings. $E_{\triangle TSolar}$ = 8.33 X 120 gallons X $\triangle T$ (difference in temperature of solar preheat tank) ÷ 1000. The units of $E_{\triangle T\ Solar}$ are kBTU.

Auxiliary thermal contribution to the domestic hot water heating load, $E_{AUX.}$ - The auxiliary thermal contribution to the domestic hot water heating load is calculated from the following equation,

$$E_{AUX.} = E_D - E_{SH},$$

since the total domestic hot water heating load, E_D, is equal to the sum of the solar and auxiliary contributions, $E_{SH} + E_{AUX.}$

Heat loss from auxiliary tank and piping between solar tank, auxiliary tank, and mixing valve, $Q_{AUX.\ Loss}$ - The heat loss from the auxiliary tank and associated piping is calculated from the formula:

$$Q_{AUX.\ Loss} = E_{AUX.\ IN} - E_{AUX.} - E_{\triangle TAUX.}$$

where,

$Q_{AUX.\ Loss}$ = heat loss from auxiliary tank and piping between solar tank, auxiliary tank and mixing valve (kBTU)

$E_{AUX.\ IN}$ = electrical thermal energy supplied to the auxiliary storage tank. $E_{AUX.\ IN}$ is determined from the reading on kilowatt-hour meter #2. The kilowatt-hour reading is multiplied by 3.413 kBTU/kilowatt-hour to yield the electrical thermal energy supplied to the auxiliary tank in kBTUs.

$E_{AUX.}$ = auxiliary thermal contribution to the domestic hot water heating load (kBTU)

$E_{\triangle TAUX.}$ = difference in heat stored in auxiliary tank at times of meter readings. $E_{\triangle TAUX.}$ = 8.33 X 120 gallons X $\triangle T$ (difference in temperature of auxiliary tank) ÷ 1000. Units are kBTU.

Operating electrical energy for the auxiliary system, $W_{AUX.}$ - The operating electrical energy for the existing electric hot water heater which is the auxiliary system is read directly from kilowatt-hour meter #2.

Percent solar contribution to the domestic hot water heating load, P - The percent solar contribution to the domestic hot water system can be calculated by the formula:

$$P = \frac{E_{SH}}{E_D} \quad X\ 100$$

where,

P = solar contribution (%)

E_{SH} = solar thermal contribution to the domestic hot water heating load (kBTU)

E_D = domestic hot water heating load (kBTU), $E_D = E_{SH} + E_{AUX.}$

Operating electrical energy for the solar energy system, W_{OP} - The operating electrical energy for the solar energy system is read directly from kilowatt-hour meter #1 which monitors the operating energy for the pump and differential temperature control.

Electricity saved, W_S - The solar contribution to the heating load, E_{SH}, is added to an estimate of the heat loss for a conventional hot water heating tank, $Q_{CONV.\ Loss}$, for the period. The difference between this

sum, expressed in units of kilowatt-hours, and the amount of electricity required to operate the solar system will be the electricity saved:

$$W_S = \frac{E_{SH} + Q_{CONV.\ Loss}}{3.413} - W_{OP}$$

where,

W_S = electricity saved (kilowatt-hours)

E_{SH} = solar contribution to the domestic hot water heating load (kBTU)

W_{OP} = operating electrical energy for the solar energy system (kilowatt-hours)

$Q_{CONV.\ Loss} = \frac{(A)\ (\Delta T_{CONV.})\ (t_{HR})}{R(1000)}$, where A is the approximate surface area of a conventional 120 gallon hot water storage tank (40 ft.^{2}); R is the insulation value (a value of 11 ^oF - hr. - ft. ^{2}/BTU was used, equivalent to the solar tank insulation); $\Delta T_{CONV.}$ is the estimated difference between the mean temperature of a conventional heating tank and ambient room temperature (^oF); and t_{HR} is the number of hours in the monitoring period. The units of $Q_{CONV.\ Loss}$ are kBTU.

The system performance indicators described above are summarized in Figure C-1,page 62 with associated symbols. Figure C-2,page 63 is the "Weekly Monitoring Raw Data Sheet" which will be used to record readings directly from the system monitoring equipment. Figure C-3,page 64 is the "Reduced Monitoring Data Sheet." The"values" on the "Reduced Monitoring Data Sheet" are calculated from the "readings" on the "Weekly Monitoring Raw Data Sheet" for each "indicator" by the following procedures.

E_{IN} - Subtract from the reading on the accumulating integrator the previously recorded reading. Multiply by 84.4 to yield the value in BTU. Divide by 1000 to yield the value in kBTU.

E_S - Subtract from the reading on BTU meter No. 1 the previously recorded reading. Multiply by 0.897 to yield the value in kBTU.

eff_{OA} - Divide E_S by E_{IN} and multiply by 100 to yield the value in percent.

E_D - Subtract from the reading on BTU meter No. 3 the previously recorded reading to yield the value in kBTU.

E_{SH} - Subtract from the reading on BTU meter No. 2 the previously recorded reading to yield the value in kBTU.

$Q_{S.T.\ Loss}$ - Subtract E_{SH} and $E_{\Delta TSolar}$ from E_S to yield the value in kBTU. $E_{\Delta TSolar} = \frac{8.33 \times 120 \times \Delta T.}{1000}$. ΔT is obtained by subtracting from the average of display points 2 & 5, the average of these points for the previous reading.

$E_{AUX.}$ - Subtract E_{SH} from E_D to yield the value in kBTU.

$Q_{AUX.\ Loss}$ - From $E_{AUX.\ IN}$ subtract $E_{AUX.}$, and then subtract $E_{\Delta TAUX.}$ to yield the value in kBTU. To obtain $E_{AUX.\ IN}$, subtract from the reading on kilowatt-hour meter No. 2 the previously recorded reading & multiply by 3.413 to yield the value in kBTU. $E_{\Delta TAUX.} = \frac{8.33 \times 120 \times \Delta T.}{1000}$. ΔT is obtained by subtracting from the average of

display point 5 and Thermometer #2, the average of these values for the previous reading.

$W_{AUX.}$ - Subtract from the reading on kilowatt-hour meter No. 2 the previously recorded reading to yield the value in kwatt-hr.

P - Divide E_{SH} by E_D. Multiply by 100 to yield the value in percent.

W_{OP} - Subtract from the reading on kilowatt-hour meter No. 1 the previously recorded reading to yield the value in kwatt-hr.

W_S - Add E_{SH} and $Q_{CONV. Loss}$. Divide this sum by 3.413, then subtract W_{OP} to yield the value in kwatt-hr.

The values will be determined weekly to aid in monitoring operation of the system. The same values will be determined monthly for submission to the Federal Highway Administration. As previously stated in addition to the values a monthly report will be submitted containing a record of maintenance and repair work with associated costs, the operational status of the solar system and monitoring system, and a record of system down time.

INDICATORS OF SYSTEM PERFORMANCE

E_{IN} - Insolation incident in the plane of the collectors

E_S - Solar thermal energy supplied to the preheat storage tank

eff_{OA} - Overall efficiency in supplying solar energy

E_D - Domestic hot water heating load demand

E_{SH} - Solar thermal contribution to the domestic hot water heating load

$Q_{S.T.\ Loss}$ - Heat loss from preheat storage tank

$E_{AUX.}$ - Auxiliary thermal contribution to the domestic hot water heating load

$Q_{AUX.\ Loss}$ - Heat loss from auxiliary tank and piping between solar tank, auxiliary tank and mixing valve

$W_{AUX.}$ - Operating electrical energy for the auxiliary system

P - Percent solar contribution to the domestic hot water heating load

W_{OP} - Operating electrical energy for the solar energy system

W_S - Electricity saved by solar hot water heating system

Figure C-1

DATE _____ TIME _____ am/

WEEKLY MONITORING RAW DATA SHEET

INSTRUMENT	READING
Accumulating Integrator (BTU/sq. ft.)	
BTU Meter No. 1 (kBTU)	
(gallons)	
BTU Meter No. 2 (kBTU)	
(gallons)	
BTU Meter No. 3 (kBTU)	
(gallons)	
Kilowatt-hour Meter No. 1 (Kwatt-hr)	
Kilowatt-hour Meter No. 2 (kwatt-hr)	
Differential Temperature Control & Performance Monitoring Unit. Display point number:	
1 - collector (^{o}F)	
2 - preheat tank storage (^{o}F)	
3 - aux. 1 - heat exchanger in (^{o}F)	
4 - aux. 2 - heat exchanger out (^{o}F)	
5 - aux. 3 - preheat tank out (^{o}F)	
6 - aux. 4 (^{o}F)	
Elapsed Time Meter (hours)	
Thermometer No. 1 - Cold water in (^{o}F)	
Thermometer No. 2 - Aux. tank out (^{o}F)	
Thermometer No. 3 - Hot water out (^{o}F)	

Figure C-2

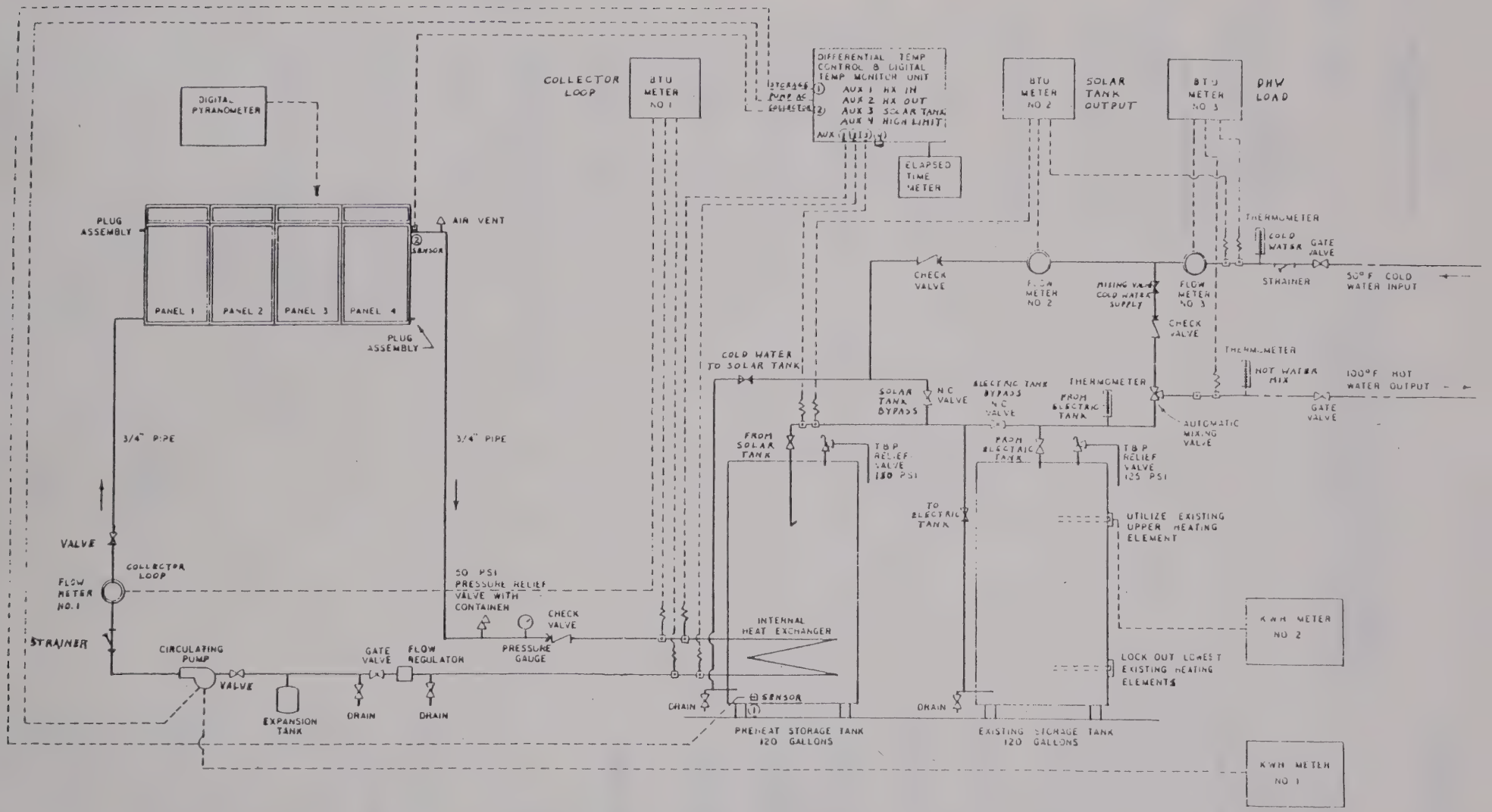
/ / - / /

DATES

REDUCED MONITORING DATA SHEET

INDICATOR	VALUE
E_{IN}	
E_S	
eff_{OA}	
E_D	
E_{SH}	
$Q_{S.T.Loss}$	
$E_{AUX.}$	
$Q_{AUX.Loss}$	
$W_{AUX.}$	
P	
W_{OP}	
W_S	

Figure C-3



SOLAR COLLECTOR SYSTEM SCHEMATIC

PIPING DIAGRAM

NOT TO SCALE

NOTE - See Appendix A, page 36 for as-built schematic.

APPENDIX D

Guide for Operation and Maintenance

of

SOLAR DOMESTIC HOT WATER SYSTEM

I287 Harding Rest Area

General Description:

The system consists of four solar collectors, a storage tank, circulating pump, expansion tank, controller, antifreeze fluid, monitoring instrumentation, and valves, pipe, fittings, etc. as necessary to complete the system. Controller turns the circulating pump on when useable heat is available at the collectors. Fluid is heated as it flows through the collectors, and the fluid heats the domestic water as it flows through the heat exchanger in the bottom of the storage tank.

Filling Antifreeze:

System should be filled when the sun is not directly on the panels. Unscrew cap on roof air vent 1 1/2 turns. With circulating pump off, pump glycol mixture into inlet valve with positive pressure pump to 25 psi pressure. Run circulating pump 10 minutes, and add additional glycol if necessary to maintain 25 psi. Install cap on inlet valve.

Draining Antifreeze:

Open drain valve and run fluid into container. Pipes are installed to drain by gravity. Retain fluid for later use.

Operation:

The system is designed to operate automatically. The controller senses temperatures at the collectors and storage tank, and turns the circulating pump on and off as appropriate for optimum heat collection.

Trouble:

If a problem occurs in the operation of the solar system, call for service immediately. Power may be shut off to the controller, pump and instrumentation by turning off the circuit breaker marked "SOLAR" in the panel box. THIS SHOULD ONLY BE DONE IF ABSOLUTELY NECESSARY.
With no fluid circulation, collector absorber plates will overheat and may cause boiling of the fluid. Daystar collectors are designed to minimize this problem. If boiling does occur, however, steam may escape from the roof air vent, and pressure may build up in the collector loop causing fluid to escape from the relief valve near the bottom of the storage tank. Once this happens, proper operation of the system cannot be restored until fluid is added to pressurize the collector loop and proper circulation is restored.

Checking Operation:

Pressure in the collector loop can be observed reading the dial pressure gauge. Pressure in the loop will vary with temperature and may drop over a period of time as entrapped air is realeased from the fluid. Pressure should never exceed 30 psi or drop below 15 psi.

Operation of the circulating pump is indicated on the controller (Independent Energy C100 System Manager) by the pilot light marked output #1. This should come on when collector temperature is 20°F higher than storage temperature, and turn off when this differential drops to 5°F. A temperature reading may be taken of these two sensors by pushing the sensor select button and observing the digital number with the appropriate pilot lit.

With the circulator pump running, proper circulation of the fluid may be observed by reading the float type flow meter near the expansion tank. Bottom of the white float inside the clear tube should read approximately 2 GPM.

Instrumentation:

Equipment for measuring various operating parameters is installed as shown on the schematic. Readout indicators are all located on the wall panel behind the storage tank, and are labeled as appropriate.

Electric Backup:

All elements except one upper element have been disconnected in the backup heater. Thermostat for this element is set all the way down at 120°F.

Mixing Valve:

This controls hot water temperature to the building, and is set at approximately 100°F. To check or adjust temperature, turn on a hot water faucet and observe thermometer marked Hot Water Mix. To adjust temperature, turn dial on top of mixing valve slightly clockwise to decrease temperature or slightly counter-clockwise to increase temperature. Keep hot water running while making these changes so results can be observed.

Maintenance:

Periodically examine pipe, valves, and tank for evidence of any leaks. Check pressure, temperatures, and fluid flow as described above in "Checking Operation." Check instrumentation readings for movement since the last reading. Check and adjust mixing valve if necessary. A qualified solar serviceman should check the system completely once a year after the hot summer season and before winter. Fluid should be checked for proper pH and freeze protection. Fluid should normally be good for five years. Excessive temperature or other unusual conditions may, however, cause premature degradation of the fluid.

Service:

Due to the unique operation and requirements of a solar system, and the danger of high temperatures or pressures possible, it is recommended that the system be serviced only by a competent solar serviceman.

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